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Original research

Correlation between body resistance and use of Far infrared-emitting garments: An exploratory evaluation

Abstract

Garments capable of generating a Far infrared (FIR) emission within a specific band of infrared electromagnetic radiation between 3μm and 1000μm (according to the classification generally used in physical and rehabilitation medicine) when stimulated are being used progressively and more extensively, especially in the world of sport. The use of FIR is generally associated with the aim of improving performance and optimizing recovery times in athletes. In this preliminary study we investigated the variation of the bioimpedance parameters that occurs when using a fabric (Accapì FIR) capable of generating a FIR infrared emission when stimulated by body heat versus a control fabric in competitive athletes subjected to acute physical stress. Preliminary results have shown that in the face of a slightly greater weight loss (which could hypothetically be due to a more efficient effect in thermoregulation secondary to the hemodynamic effect) but which in practice is considerably comparable (considering the relative *p*-values obtained by statistical analysis), the use of FIR fabric is related to a statistically significant reduction in body resistance (Rz) compared to the control fabric. In general, this effect correlates with a different distribution of fluids and ions, which allows the body to oppose a lower resistance to the passage of the microcurrent used in the bioimpedance measurement. This outlines a picture that is the opposite to what one would expect to observe following acute physical activity. This effect could be explained on the basis of the most recent interpretation of these phenomena in literature, i.e. by the ability to intervene on blood circulation (hemodynamic effect) in the areas included within the penetration capacity of the FIR frequencies. The haemodynamic effect is potentially correlated to positive metabolic and thermoregulatory effects, favourable elements in sports practice. Further future studies on larger samples and with a further level of detail are necessary to clarify all the potential associated with the use of FIR garments.

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Introduction

The sports sector can represent for human performance what Formula 1 represents for the automotive sector: a test bed where new concepts are explored that might identify and optimize successful strategies that can be applied to even the most common daily uses. With this in mind, the sports sector is constantly researching new ways to optimize the performance of the human body. Sports clothing is one of the richest and most successful areas of research. Garments capable of controlling temperature or humidity with different technologies and promoting circulation and muscle contraction are consolidated realities in top-level sporting practice and are considered essential to performance and recovery. Clothing capable of emitting Far infrared (FIR) is a relatively recent area of investigation. FIR is a specific band of electromagnetic radiation. While different classifications use different boundaries, FIR can be categorized according to the general classification proposed by Byrnes et al from 15μm to 1000μm, therefore falling within the infrared spectrum (IR). Within 8μm to 15μm there are long-wavelength infrared (LWIR/IR-C DIN) and within 3μm to 8μm there are mid-wavelength infrared (MWIR/IR-C DIN) [1]. However, the classifications for FIR commonly used in physical therapy and rehabilitation – infrared radiation between 3μm and 1000μm – corresponds with the definition proposed by Zati and Valent [2].

Any object or living organism, including humans, with a temperature higher than absolute zero radiates FIR radiation into the surrounding environment. FIR emission cannot be seen with the human eye. It is detected by the integumentary system, through skin thermoreceptors, which identify it as radiant heat. FIR radiation can also be absorbed at tissue level up to a depth of 4cm [3] – a level within which FIR radiation could – at least in theory – alter biological functions through cellular and molecular stimulation (e.g. cytochrome-c-oxidase and intracellular water) [3]. These potentials are generally attributed to the high level of hydration of human tissues.

FIR technology has long been used in the medical and physiotherapy fields to treat various pathological and para-physiological conditions involving muscle and joint pain and fatigue, wound healing, heart failure, sleep disorders, breastfeeding problems and dysmenorrhoea, etc. [3]. The majority of studies aimed at clarifying the biological mechanisms connected to the use of FIR technology have been carried out *in vitro* or in animal models, highlighting a potential application in the management of inflammatory processes [4], oxidative stress [5], muscle tendon function and integumentary function [6] and in the control of microbial development [7]. These applications are proposed with the aim of delaying muscle fatigue [8], promoting circulation, particularly the peripheral microcirculation (within the areas reachable by FIR frequencies) [9,10] and cerebral microcirculation [11] – a combination that overall could also exert effects from a metabolic point of view [9].

Over time, in addition to fabrics [12], FIR emission has been achieved with different technological approaches from complex FIR-cabins to lamps or other types of emitters [3]. For obvious technical and logistical reasons, FIR fabrics represent the most versatile solution in the application of FIR in sporting activity. Garments capable of emitting FIR are generally made by incorporating bioceramic fibres or powders with different technologies (e.g. magnesium, silica, tourmaline or noble metals) either directly into the fibres used to make the fabrics, intertwined with the fibres used to make the fabrics or with plates applied to the fabric in specific areas. Once irradiated with the infrared frequencies emitted by the body, bioceramics can return an FIR emission [13]. In practice, there should be an absorption of the thermal energy emitted by the body in the form of IR, temperature stability (at room temperature the FIR fabrics do not exert a heating effect) [14] and a re-emission in the characteristic wavelength of the FIR towards the body, exploiting the natural mechanisms of convection and conduction. For this reason, the effects of FIR fabrics can be considered as oriented towards obtaining a biological response and not towards temperature control. In this regard, several authors have described an effect of muscle oxygenation [15,16], probably deriving from an increase in peripheral blood flow [15], with effects that can be observed on the resting metabolic rate [17] and on the subjective parameters of sleep [18]. A recent review work by Bontemps et al considered the use of state-of-the-art FIR fabrics, highlighting how the main mechanisms of action are related to alterations in the thermoregulatory and haemodynamic response, with useful results in the medical and physiotherapy fields [19]. In the sports field, the optimization of physical performance and post-exercise recovery seem are of the greatest interest [19]. Considering these aspects relating to thermoregulation and haemodynamics, the present work aims to investigate whether carrying out a short and intense physical activity while wearing FIR fabrics against an inert control fabric, can lead to detectable effects on the bioelectrical parameters of the human organism such as resistance (Rz) and reactance (Rx).

Materials and methods

This double-blind, randomized, placebo-controlled exploratory study evaluated trail running athletes who underwent high-intensity training stress under controlled conditions, wearing FIR-fabric technical clothing or with conventional technical fabrics without FIR technology in different evaluation sessions.

The exploratory evaluations and data analysis were conducted in accordance with the rules of good clinical practice set by the Declaration of Helsinki and in accordance with the European Union Directive 2001/20/EC [20]. Each participant received, approved, and signed an informed consent form, privacy policy disclosure documents, and approved data analysis and publication.

Participants

The study enrolled ten trail running competitive athletes with at least five years of competitive sporting practice. The athletes were at a level of training such as to guarantee, without preparation outside the conventional training routine, the participation in competitive events over distances greater than 20km with altitude differences greater than 500m. All evaluated athletes were male, with a mean age of 40.9 (± 5.9) years, mean weight of 78.3 (± 8.9) kg, mean height of 1.76 (± 0.05) cm and a BMI of 25.3 (± 2.9) kg /m^2, as indicated in **Table 1.**

Characteristics of the participants	
Age	40.9 (±5.9) years
Weight	78.3 (± 8.9) kg
Height	1.76 (± 0,05) cm
BMI	25.3 (± 2.9) kg/m^2

Table 1: Characteristics of enrolled participants

Inclusion and exclusion criteria

The criteria for inclusion were being in possession of a valid sport medical certification for competitive activity, participating in the competitive practice of trail running for at least five years and having an average level of training such as to guarantee, without the implementation of particular training programmes, participation in competitive events over distances of more than 20km with altitude differences greater than 500m.

Exclusion criteria included the use of medicines, use of drugs, alcohol abuse, inadequate possibility of physical/muscular recovery following competitions and training, injuries suffered in the last 60 days not fully recovered (with medical documentation), inability to practise competitive physical activity (even temporarily), paramorphisms, pain of any kind.

Evaluated products

During evaluations, athletes wore a full body technical training suit marketed under the name Accapì FIR (Bruno Chiaruttini S.r.l. – Rezzato, BS, Italy). The suit was made from polyester fibres including noble metals able to produce MWIR, LWIR and FIR frequencies when stimulated by the infrared frequency produced by the athlete (a constant infrared emission of between 5μm and 20μm). The control product was made with the same polyester fibre excluding the presence of metal components. Both tested products were made in Italy. Both the products with Accapì FIR technology and the control product comply with the ISO 10993-1 standard in relation to cytotoxicity (UNI EN ISO 10993-5:2009, Report 4983-20 of 07/16/2020), skin irritation (UNI EN ISO 10993-10:2013, Report 8742-20 of 22/12/2020), allergic potential from contact dermatitis (rLLNA) (UNI EN ISO 10993-1:2013, Report 8741-20 of 22/12/ 2020). This confirms the absence of cytotoxicity, sensitization and irritation reactions.

Evaluation and analysis

Prior to evaluation, participants were provided with a kit containing the Accapì FIR technical suit and the technical suit made with the control fabric. To participants and examiners, the suits were indistinguishable from each other. The athletes were summoned to a temperature and humidity-controlled laboratory environment (temperature 22°C, humidity 50%) and left to acclimatize for 15 minutes wearing only underwear. The weight and height of each participant were recorded and a BIVA (bioimpedance vectorial analysis) was completed. Mass and height were measured with a mechanical column scale SECA 700 Eye Level Beam (SECA North America - Medical Measuring Systems and Scales - 13601 Benson Avenue Chino, CA 91710 USA); mass was measured with the approximation of 50g; height was measured to the nearest 0.1cm [20]. BIVA, providing the impedance values in its Rz and Xc components, was completed using a bioimpedance analyzer (BIA 101 Anniversary Sport Edition, Akern, Florence, Italy) in combination with the Bodygram Plus® software, employing Biatrodes electrodes in strict compliance with the manufacturer's protocol. The participants enrolled in this study did not follow any specific instructions such as diet, hydration or physical activity prior to BIA measurements.

Participants lay supine on a non-conductive surface for at least two minutes prior to measurements, allowing for even distribution of body fluids. They were then positioned with the legs opened at a 45° angle with respect to the midline of the body and upper limbs positioned at a 30° angle from the trunk. This was to verify the absence of contact with any metallic object and the absence of contact between the upper limbs and trunk and between the lower limbs. After cleansing the skin with alcohol, four electrodes (Biatrodes, Akern Srl, Florence, Italy) were applied at a distance of 5cm from each other; two on the back of the right hand, corresponding with the radioulnar joint and the metacarpophalangeal joint of the third finger; and two on the dorsum of the foot – one at the ankle joint and the other at the metatarsophalangeal joint of the third toe [21–24].

The data obtained were processed using the Bodygram Plus software by analyzing the direct values and obtaining the relative derived estimates. All instruments used to provide for the possibility of calibration were calibrated before each measurement session according to the indications provided by the manufacturers. Once all measurements were taken, the participants underwent a subsequent 30 minutes of adaptation to environmental conditions wearing the technical garment. After this phase, they performed an incremental work protocol on a Treadmil Run Excite Jog 500 (Technogym s.p.a Cesena FC Italia), starting from a run at 8 km/h for two minutes, increasing the speed by 2 km/hr every two minutes until they reached a speed of 18 km/hr for a total work time of 12 minutes. Subsequently, the technical clothing was removed, and after a wait period of 15 minutes to acclimatize and return to a state of stillness, the measurements were carried out again. After a seven-day complete recovery period where subjects were instructed in uniform physical activity management, the test protocol was repeated using the control fabric not used in the first evaluation.

The statistical analysis of the results was carried out by reporting the measured variables as mean and standard deviation; the variations of the variables (Δ) is expressed as the difference between the averages at T_0 and at T_1. The Student's t-test was used to verify if the use of Accapí fabric is significantly associated with variations in weight, Rz and Xc; the level of significance was set at 0.05 and analyses were performed using Excel 365 (Microsoft corporation, Redmont Washington, USA).

Results

The analysis of the anthropometric parameters shows an overlapping weight variation between the two evaluation sessions (0.39kg against 0.25kg) using the complete Accapì FIR and the control product respectively. The analysis of the bioimpedance parameters suggests a more complex situation. With the use of Accapì FIR garments, a reduction of Rz in 2.8 Ω/m and in Xc of 2.3 Ω/m is observed, an element of particular importance if related to the weight reduction, probably attributable with such a short stress to the loss of fluids through sweating. In such a situation, an increase in Rx and an essentially unchanged Xc is expected – as occurs using the control fabric. Noteworthy is the fact that despite the reduced number for the Rz parameter, statistical significance was reached ($p<0.05$) as illustrated in **Table 1**. The reduction in resistance in the presence of greater acute weight loss, observed using the Accapì FIR fabric, compared to an observed increase in resistance in the presence of greater weight loss (**Fig. 1**), seems to suggest an effect of Accapì FIR fabric on the dynamics of distribution of body fluids, as one would expect in situations of this type.

	Weight T_0	Weight T_1	Δ Weight	Rz 1	Rz 2	Δ Rz	Xc 1	Xc 2	Δ Xc
Accapì FIR	78.3±8.9	77.9±9.0	-0.39	388.5±74.0	385.7±38.5	-2.80	54.20±10.0	51.90±6.5	-2.30
Control	78.2±9.3	77.97±9.2	-0.25	432.90±51.4	434.1±55.5	1.20	55.10±6.5	55.20±6.4	0.10
P(t)	0.98	0.99		0.14	0.04		0.81	0.27	

Table 1: Pre- and post-exercise bioimpedance parameters

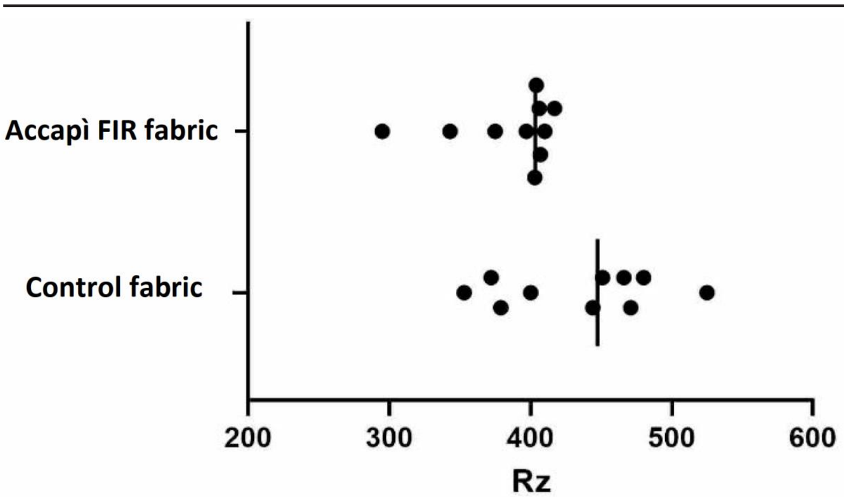

Figure 1: Resistance values in the two experimental groups

Discussion

Preliminary results have shown that in the face of a slightly greater weight loss, which in practice can be considered as superimposable, the use of Accapì FIR technology garments is correlated to a statistically significant reduction in body resistance (Rz) compared to the control fabric. This effect can generally be correlated to a different distribution of fluids and ions, which allows an organism to oppose a lower resistance to the passage of the microcurrent used in bioimpedance measurement, outlining a picture opposite to what one would expect to observe following the practice of acute physical activity. The effect could be explained on the basis of the most recent interpretation of these phenomena in literature, i.e. by the ability to intervene on blood circulation (hemodynamic effect) [10,15] in the areas included within the penetration capacity of the FIR frequencies [2,19]. From a theoretical-rational point-of-view, this phenomenon should be correlated to an effect in the dynamics of peripheral circulation (e.g. by intervening on the capillary and superficial circulation), which can also be associated with a more long term efficient management of body heat (**Fig. 2**). This effect could potentially contribute to a more efficient management of the peripheral circulation – a phenomenon correlated to various aspects such as the supply of oxygen, water and nutrients to the tissues and the removal of catabolites. These aspects can prove to be very important during physical activity and during recovery and the during the supercompensation processes, also potentially providing a better thermoregulation capacity. The *p*-values relating to weight variations allow them to be considered as non-significant. It is possible to hypothesize speculatively that the additional 140g lost when using FIR fabrics is attributable to a more efficient effect in thermoregulation that is secondary to the hemodynamic effect. However, this speculative hypothesis must be considered with caution and should be the subject of further studies. The sum of these haemodynamic and thermoregulatory effects could represent an interesting solution to modulate the reduction in performance during activity and favour the recovery and supercompensation processes [5,16,19]. Noteworthy is the fact that other advantages relating to the use of FIR fabrics described in literature include improvement in postural control found in both experienced and untrained athletes [19, 25] and a modest improvement in performance [13,19]. Given that FIR fabric exhibits bacteriostatic and cooling capabilities, it could greatly contribute to improving the comfort of the athlete during long-lasting exercise [7,19].

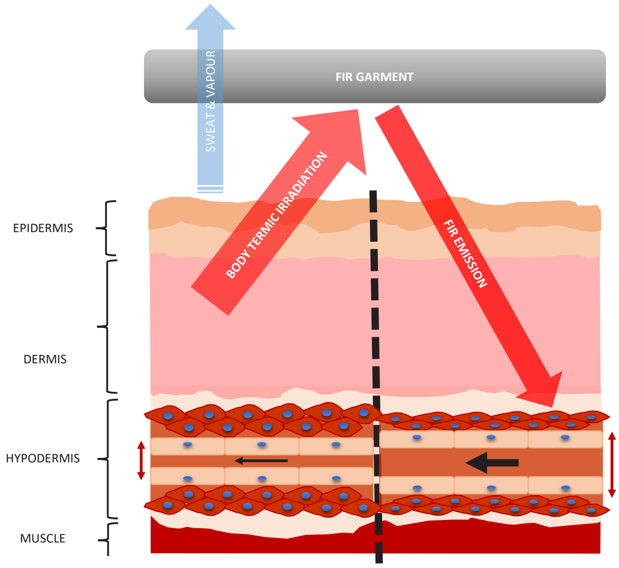

Figure 2: Hypothesis of the mechanism responsible for the observed Rz variations: The body heat emission is filtered and selectively reflected by the FIR garment. This affects the structures included within its penetration capacity and favours vasodilatation. Vasodilatation favours the haematological dynamics potentially responsible for greater fabric perfusion and therefore a reduction in Rz.

Conclusions

In this work we have studied the variation of the bioimpedance parameters that occurs when using Accapì FIR garments capable of generating an FIR infrared emission when stimulated by body heat according to the classification proposed by Zati and Valent [2] against a control fabric in recreational athletes subjected to acute physical stress. The preliminary results have shown that, in the face of a slightly greater weight loss (which could hypothetically be due to a more efficient effect in thermoregulation secondary to the hemodynamic effect), but in practice considered as superimposable considering the relative p-values obtained by statistical analysis, the use of FIR fabric is correlated to a statistically significant reduction in body resistance (Rz) compared to the control fabric. This effect is generally correlated to a different distribution of fluids and ions, which allows the body to oppose less resistance to the passage of the microcurrent used in the bioimpedance measurement. This outlines a picture that is opposite to what one would expect to observe following acute physical activity.

Limitations of this study are the small number of the sample studied, the absence of further evaluation methods such as thermographic monitoring and the evaluation of athletes' cortisol and lactate, elements, which could provide a fuller vision of the phenomenon. A significant strong point is the achievement of a statistically significant datum in the Rz parameter with such a small number. Further future studies on larger samples and with a further level of detail will be necessary to clarify all the potential associated with the use of FIR garments.

Author contributions

All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

A Bertuccioli works as a scientific consultant for the company responsible for developing Accapì Fir-Fibre garments.

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